

## **GAMS (Guide to Available Math Software)**

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## Preface

- Scope: The Guide to Available Mathematical Software (GAMS) is a detailed, hierarchical classification scheme developed by the U.S. National Institute of Standards and Technology (NIST), formerly called the National Bureau of Standards, and published by R. Boisvert, S. Howe, and D. Kahaner in "The GAMS Classification Scheme for Mathematical and Statistical Software," ACM SIGNUM Newsletter, 18 (January, 1983), 10-18.
- This document reprints all the subject headings in the GAMS scheme, along with the unique category code for each, in hierarchical order. LC uses the GAMS headings to provide subject (task-oriented) descriptions of subroutines in local math libraries (e.g., SLATEC). GAMS also serves as the organizing framework for LC's LINMath (URL: <http://www.llnl.gov/LCdocs/nmg1>) math-subroutine access and advice web sites (open and secure). With LINMath, you walk down branches of the GAMS tree layer by layer to find subroutines, while with this document you can survey the entire tree comprehensively and comparatively.
- NIST maintains the original GAMS web site (URL: <http://gams.nist.gov>) ([gams.nist.gov](http://gams.nist.gov)).
- Availability: The GAMS-using LINMath web site is on the open network, but available only to machines in the LLNL domain. A comparable site serves the secure network.
- Consultant: For help contact the LC customer service and support hotline at 925-422-4531 (open e-mail: [lc-hotline@llnl.gov](mailto:lc-hotline@llnl.gov), secure e-mail: [lc-hotline@pop.llnl.gov](mailto:lc-hotline@pop.llnl.gov)).
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# **GAMS Subject Headings**

## **A. Arithmetic**

A. Arithmetic, error analysis  
A1. Integer  
A2. Rational  
A3. Real  
A3A. Single precision  
A3B. Double precision  
A3C. Extended precision  
A3D. Extended range  
A4. Complex  
A4A. Single precision  
A4B. Double precision  
A4C. Extended precision  
A4D. Extended range  
A5. Interval  
A5A. Real  
A5B. Complex  
A6. Change of representation  
A6A. Type conversion  
A6B. Base conversion  
A6C. Decomposition, construction  
A7. Sequences (e.g., convergence acceleration)

## **B. Number Theory**

B. Number theory

## C. Elementary and Special Functions

- C. Elementary and special functions (search also class L5)
  - C1. Integer-valued functions (e.g., floor, ceiling, factorial, binomial coefficient)
  - C2. Powers, roots, reciprocals
  - C3. Polynomials
    - C3A. Orthogonal
      - C3A1. Trigonometric
      - C3A2. Chebyshev, Legendre
      - C3A3. Laguerre
      - C3A4. Hermite
    - C3B. Non-orthogonal
  - C4. Elementary transcendental functions
    - C4A. Trigonometric, inverse trigonometric
    - C4B. Exponential, logarithmic
    - C4C. Hyperbolic, inverse hyperbolic
    - C4D. Integrals of elementary transcendental functions
  - C5. Exponential and logarithmic integrals
  - C6. Cosine and sine integrals
  - C7. Gamma
    - C7A. Gamma, log gamma, reciprocal gamma
    - C7B. Beta, log beta
    - C7C. Psi function
    - C7D. Polygamma function
    - C7E. Incomplete gamma
    - C7F. Incomplete beta
    - C7G. Riemann zeta
  - C8. Error functions
    - C8A. Error functions, their inverses, integrals, including the normal

distribution function

- C8B. Fresnel integrals
- C8C. Dawson's integral
- C9. Legendre functions
- C10. Bessel functions
- C10A.  $J$ ,  $Y$ ,  $H_{-}(1)$ ,  $H_{-}(2)$
- C10A1. Real argument, integer order
- C10A2. Complex argument, integer order
- C10A3. Real argument, real order
- C10A4. Complex argument, real order
- C10A5. Complex argument, complex order
- C10B.  $I$ ,  $K$
- C10B1. Real argument, integer order
- C10B2. Complex argument, integer order
- C10B3. Real argument, real order
- C10B4. Complex argument, real order
- C10B5. Complex argument, complex order
- C10C. Kelvin functions
- C10D. Airy and Scorer functions
- C10E. Struve, Anger, and Weber functions
- C10F. Integrals of Bessel functions
- C11. Confluent hypergeometric functions
- C12. Coulomb wave functions
- C13. Jacobian elliptic functions, theta functions
- C14. Elliptic integrals
- C15. Weierstrass elliptic functions
- C16. Parabolic cylinder functions
- C17. Mathieu functions

C18. Spheroidal wave functions

C19. Other special functions

## D. Linear Algebra

### D. Linear Algebra

#### D1. Elementary vector and matrix operations

##### D1A. Elementary vector operations

D1A1. Set to constant

D1A2. Minimum and maximum components

D1A3. Norm

D1A3A. L-1 (sum of magnitudes)

D1A3B. L-2 (Euclidean norm)

D1A3C. L-infinity (maximum magnitude)

D1A4. Dot product (inner product)

D1A5. Copy or exchange (swap)

D1A6. Multiplication by scalar

D1A7. Triad ( $a*x+y$  for vectors  $x,y$  and scalar  $a$ )

D1A8. Elementary rotation (Givens transformation)

D1A9. Elementary reflection (Householder transformation)

D1A10. Convolutions

##### D1B. Elementary matrix operations

D1B1. Set to zero, to identity

D1B2. Norm

D1B3. Transpose

D1B4. Multiplication by vector

D1B5. Addition, subtraction

D1B6. Multiplication

D1B7. Matrix polynomial

D1B8. Copy

D1B9. Storage mode conversion

D1B10. Elementary rotation (Givens transformation)

D1B11. Elementary reflection (Householder transformation)

D2. Solution of systems of linear equations (including inversion, LU and related decompositions)

D2A. Real nonsymmetric matrices

D2A1. General

D2A2. Banded

D2A2A. Tridiagonal

D2A3. Triangular

D2A4. Sparse

D2B. Real symmetric matrices

D2B1. General

D2B1A. Indefinite

D2B1B. Positive definite

D2B2. Positive definite banded

D2B2A. Tridiagonal

D2B4. Sparse

D2C. Complex non-Hermitian matrices

D2C1. General

D2C2. Banded

D2C2A. Tridiagonal

D2C3. Triangular

D2C4. Sparse

D2D. Complex Hermitian matrices

D2D1. General

D2D1A. Indefinite

D2D1B. Positive definite

D2D2. Positive definite banded

D2D2A. Tridiagonal

D2D4. Sparse

D2E. Associated operations (e.g., matrix reorderings)

D3. Determinants

D3A. Real nonsymmetric matrices

D3A1. General

D3A2. Banded

D3A2A. Tridiagonal

D3A3. Triangular

D3A4. Sparse

D3B. Real symmetric matrices

D3B1. General

D3B1A. Indefinite

D3B1B. Positive definite

D3B2. Positive definite banded

D3B2A. Tridiagonal

D3B4. Sparse

D3C. Complex non-Hermitian matrices

D3C1. General

D3C2. Banded

D3C2A. Tridiagonal

D3C3. Triangular

D3C4. Sparse

D3D. Complex Hermitian matrices

D3D1. General

D3D1A. Indefinite

D3D1B. Positive definite

D3D2. Positive definite banded

D3D2A. Tridiagonal

D3D4. Sparse

D4. Eigenvalues, eigenvectors

D4A. Ordinary eigenvalue problems ( $Ax = (\lambda) * x$ )

D4A1. Real symmetric

D4A2. Real nonsymmetric

D4A3. Complex Hermitian

D4A4. Complex non-Hermitian

D4A5. Tridiagonal

D4A6. Banded

D4A7. Sparse

D4B. Generalized eigenvalue problems (e.g.,  $Ax = (\lambda)*Bx$ )

D4B1. Real symmetric

D4B2. Real general

D4B3. Complex Hermitian

D4B4. Complex general

D4B5. Banded

D4C. Associated operations

D4C1. Transform problem

D4C1A. Balance matrix

D4C1B. Reduce to compact form

D4C1B1. Tridiagonal

D4C1B2. Hessenberg

D4C1B3. Other

D4C1C. Standardize problem

D4C2. Compute eigenvalues of matrix in compact form

D4C2A. Tridiagonal

D4C2B. Hessenberg

D4C2C. Other

D4C3. Form eigenvectors from eigenvalues

D4C4. Back transform eigenvectors

D4C5. Determine Jordan normal form

D5. QR decomposition, Gram-Schmidt orthogonalization

D6. Singular value decomposition

D7. Update matrix decompositions

D7A. LU

- D7B. Cholesky
- D7C. QR
- D7D. Singular value
- D8. Other matrix equations (e.g.,  $AX+XB=C$ )
- D9. Overdetermined or underdetermined systems of equations, singular systems, pseudo-inverses (search also classes D5, D6, K1a, L8a)

## **E. Interpolation**

E. Interpolation  
E1. Univariate data (curve fitting)  
E1A. Polynomial splines (piecewise polynomials)  
E1B. Polynomials  
E1C. Other functions (e.g., rational, trigonometric)  
E2. Multivariate data (surface fitting)  
E2A. Gridded  
E2B. Scattered  
E3. Service routines (e.g., grid generation, evaluation of fitted functions) (search also class N5)

## **F. Solution of Nonlinear Equations**

F. Solution of nonlinear equations  
F1. Single equation  
F1A. Smooth  
F1A1. Polynomial  
F1A1A. Real coefficients  
F1A1B. Complex coefficients  
F1A2. Nonpolynomial  
F1B. General (no smoothness assumed)  
F2. System of equations  
F2A. Smooth  
F2B. General (no smoothness assumed)  
F3. Service routines (e.g., check user-supplied derivatives)

## G. Optimization

G. Optimization (search also classes K, L8)

G1. Unconstrained

G1A. Univariate

G1A1. Smooth function

G1A1A. User provides no derivatives

G1A1B. User provides first derivatives

G1A1C. User provides first and second derivatives

G1A2. General function (no smoothness assumed)

G1B. Multivariate

G1B1. Smooth function

G1B1A. User provides no derivatives

G1B1B. User provides first derivatives

G1B1C. User provides first and second derivatives

G1B2. General function (no smoothness assumed)

G2. Constrained

G2A. Linear programming

G2A1. Dense matrix of constraints

G2A2. Sparse matrix of constraints

G2B. Transportation and assignments problem

G2C. Integer programming

G2C1. Zero/one

G2C2. Covering and packing problems

G2C3. Knapsack problems

G2C4. Matching problems

G2C5. Routing, scheduling, location problems

G2C6. Pure integer programming

G2C7. Mixed integer programming

G2D. Network (for network reliability search class M)

G2D1. Shortest path

G2D2. Minimum spanning tree

G2D3. Maximum flow

G2D3A. Generalized networks

G2D3B. Networks with side constraints

G2D4. Test problem generation

G2E. Quadratic programming

G2E1. Positive definite Hessian (i.e. convex problem)

G2E2. Indefinite Hessian

G2F. Geometric programming

G2G. Dynamic programming

G2H. General nonlinear programming

G2H1. Simple bounds

G2H1A. Smooth function

G2H1A1. User provides no derivatives

G2H1A2. User provides first derivatives

G2H1A3. User provides first and second derivatives

G2H1B. General function (no smoothness assumed)

G2H2. Linear equality or inequality constraints

G2H2A. Smooth function

G2H2A1. User provides no derivatives

G2H2A2. User provides first derivatives

G2H2A3. User provides first and second derivatives

G2H2B. General function (no smoothness assumed)

G2H3. Nonlinear constraints

G2H3A. Equality constraints only

G2H3A1. Smooth function and constraints

G2H3A1A. User provides no derivatives

G2H3A1B. User provides first derivatives of function and constraints

G2H3A1C. User provides first and second derivatives of function and constraints

G2H3A2. General function and constraints (no smoothness assumed)

G2H3B. Equality and inequality constraints

G2H3B1. Smooth function and constraints

G2H3B1A. User provides no derivatives

G2H3B1B. User provides first derivatives of function and constraints

G2H3B1C. User provides first and second derivatives of function and constraints

G2H3B2. General function and constraints (no smoothness assumed)

G2I. Global solution to nonconvex problems

G3. Optimal control

G4. Service routines

G4A. Problem input (e.g., matrix generation)

G4B. Problem scaling

G4C. Check user-supplied derivatives

G4D. Find feasible point

G4E. Check for redundancy

G4F. Other

## H. Differentiation, Integration

H. Differentiation, integration

H1. Numerical differentiation

H2. Quadrature (numerical evaluation of definite integrals)

H2A. One-dimensional integrals

H2A1. Finite interval (general integrand)

H2A1A. Integrand available via user-defined procedure

H2A1A1. Automatic (user need only specify required accuracy)

H2A1A2. Nonautomatic

H2A1B. Integrand available only on grid

H2A1B1. Automatic (user need only specify required accuracy)

H2A1B2. Nonautomatic

H2A2. Finite interval (specific or special type integrand including weight functions, oscillating and singular integrands, principal value integrals, splines, etc.)

H2A2A. Integrand available via user-defined procedure

H2A2A1. Automatic (user need only specify required accuracy)

H2A2A2. Nonautomatic

H2A2B. Integrand available only on grid

H2A2B1. Automatic (user need only specify required accuracy)

H2A2B2. Nonautomatic

H2A3. Semi-infinite interval (including  $e^{**(-x)}$  weight function)

H2A3A. Integrand available via user-defined procedure

H2A3A1. Automatic (user need only specify required accuracy)

H2A3A2. Nonautomatic

H2A4. Infinite interval (including  $e^{**(-x^{**2})}$  weight function)

H2A4A. Integrand available via user-defined procedure

H2A4A1. Automatic (user need only specify required accuracy)

H2A4A2. Nonautomatic

H2B. Multidimensional integrals

H2B1. One or more hyper-rectangular regions

H2B1A. Integrand available via user-defined procedure

H2B1A1. Automatic (user need only specify required accuracy)

H2B1A2. Nonautomatic

H2B1B. Integrand available only on grid

H2B1B1. Automatic (user need only specify required accuracy)

H2B1B2. Nonautomatic

H2B2. Nonrectangular region, general region

H2B2A. Integrand available via user-defined procedure

H2B2A1. Automatic (user need only specify required accuracy)

H2B2A2. Nonautomatic

H2B2B. Integrand available only on grid

H2B2B1. Automatic (user need only specify required accuracy)

H2B2B2. Nonautomatic

H2C. Service routines (compute weight and nodes for quadrature formulas)

# I. Differential and Integral Equations

- I. Differential and integral equations
  - I1. Ordinary differential equations
    - I1A. Initial value problems
      - I1A1. General, nonstiff or mildly stiff
        - I1A1A. One-step methods (e.g., Runge-Kutta)
        - I1A1B. Multistep methods (e.g., Adams' predictor-corrector)
        - I1A1C. Extrapolation methods (e.g., Bulirsch-Stoer)
      - I1A2. Stiff and mixed algebraic-differential equations
    - I1B. Multipoint boundary value problems
      - I1B1. Linear
      - I1B2. Nonlinear
      - I1B3. Eigenvalue (e.g., Sturm-Liouville)
    - I1C. Service routines (e.g., interpolation of solutions, error handling)
  - I2. Partial differential equations
    - I2A. Initial boundary value problems
      - I2A1. Parabolic
        - I2A1A. One spatial dimension
        - I2A1B. Two or more spatial dimensions
      - I2A2. Hyperbolic
    - I2B. Elliptic boundary value problems
      - I2B1. Linear
        - I2B1A. Second order
          - I2B1A1. Poisson (Laplace) or Helmholtz equation
            - I2B1A1A. Rectangular domain (or topologically rectangular in the coordinate system)
            - I2B1A1B. Nonrectangular domain
            - I2B1A2. Other separable problems
            - I2B1A3. Nonseparable problems
            - I2B1C. Higher order equations (e.g., biharmonic)
          - I2B2. Nonlinear
          - I2B3. Eigenvalue
          - I2B4. Service routines
            - I2B4A. Domain triangulation (search also class P2a2c1)
            - I2B4B. Solution of discretized elliptic equations
        - I2B4A. Domain triangulation (search also class P2a2c1)
        - I2B4B. Solution of discretized elliptic equations
      - I3. Integral equations

## **J. Integral Transforms**

```
J.  Integral transforms
J1.    Fast Fourier transforms (search class L10 for time series analysis)
J1A.   One-dimensional
J1A1.  Real
J1A2.  Complex
J1A3.  Trigonometric (sine, cosine)
J1B.   Multidimensional
J2.   Convolutions
J3.   Laplace transforms
J4.   Hilbert transforms
```

## K. Approximation

K. Approximation (search also class L8)  
K1. Least squares (L-2) approximation  
K1A. Linear least squares (search also classes D5, D6, D9)  
K1A1. Unconstrained  
K1A1A. Univariate data (curve fitting)  
K1A1A1. Polynomial splines (piecewise polynomials)  
K1A1A2. Polynomials  
K1A1A3. Other functions (e.g., rational, trigonometric,  
          user-specified)  
K1A1B. Multivariate data (surface fitting)  
K1A2. Constrained  
K1A2A. Linear constraints  
K1A2B. Nonlinear constraints  
K1B. Nonlinear least squares  
K1B1. Unconstrained  
K1B1A. Smooth functions  
K1B1A1. User provides no derivatives  
K1B1A2. User provides first derivatives  
K1B1A3. User provides first and second derivatives  
K1B1B. General functions  
K1B2. Constrained  
K1B2A. Linear constraints  
K1B2B. Nonlinear constraints  
K2. Minimax (L-infinity) approximation  
K3. Least absolute value (L-1) approximation  
K4. Other analytic approximations (e.g., Taylor polynomial, Pade)  
K5. Smoothing  
K6. Service routines (e.g., mesh generation, evaluation of fitted  
      functions) (search also class N5)

## L. Statistics, Probability

L. Statistics, probability

L1. Data summarization

L1A. One univariate quantitative sample

L1A1. Ungrouped data

L1A1A. Location

L1A1B. Dispersion

L1A1C. Shape

L1A1D. Distribution, density

L1A2. Ungrouped data with missing values

L1A3. Grouped data

L1A3A. Location

L1A3B. Dispersion

L1A3C. Shape

L1C. One univariate qualitative (proportional) sample

L1E. Two or more univariate samples or one multivariate sample

L1E1. Ungrouped data

L1E1A. Location

L1E1B. Correlation

L1E2. Ungrouped data with missing values

L1E3. Grouped data

L1F. Two or more multivariate samples

L2. Data manipulation (search also class N)

L2A. Transform (search also class N6 for sorting, ranking)

L2B. Group

L2C. Sample

L2D. Subset

L3. Graphics (search also class Q)

L3A. Histograms

L3B. Distribution functions

L3C. Scatter diagrams

L3C1. Y vs. X

L3C2. Symbol plots

L3C3. Multiple plots

L3C4. Probability plots

L3C4B. Beta, binomial

L3C4C. Cauchy, chi-squared

L3C4D. Double exponential

L3C4E. Exponential, extreme value

L3C4F. F distribution

L3C4G. Gamma, geometric

L3C4H. Halfnormal

L3C4L. Lambda, logistic, lognormal

L3C4N. Negative binomial, normal

L3C4P. Pareto, Poisson

L3C4T. t distribution

L3C4U. Uniform

L3C4W. Weibull

L3C5. Time series plots ( $X(i)$  vs.  $i$ , vertical, lag)

L3D. EDA graphics

L4. Elementary statistical inference, hypothesis testing

L4A. One univariate quantitative sample

L4A1. Ungrouped data

L4A1A. Parameter estimation

L4A1A2. Binomial

L4A1A5. Extreme value

L4A1A14. Normal

L4A1A16. Poisson

L4A1A21. Uniform

L4A1A23. Weibull

L4A1B. Distribution-free (nonparametric) analysis

L4A1C. Goodness-of-fit tests

L4A1D. Tests on sequences of numbers

L4A1E. Density and distribution function estimation

L4A1F. Tolerance limits

L4A2. Ungrouped data with missing values

L4A3. Grouped data

L4A3A. Parameter estimation

L4A3A14. Normal

L4B. Two or more univariate quantitative samples

L4B1. Ungrouped data

L4B1A. Parameter estimation

L4B1A14. Normal

L4B1B. Distribution-free (nonparametric) analysis

L4B2. Ungrouped data with missing values

L4B3. Grouped data

L4C. One univariate qualitative (proportional) sample

L4D. Two or more univariate samples

L4E. One multivariate sample

L4E1. Ungrouped data

L4E1A. Parameter estimation

L4E1A14. Normal

L4E1B. Distribution-free (nonparametric) analysis

L4E2. Ungrouped data with missing values

L4E2A. Parameter estimation

L4E2B. Distribution-free (nonparametric) analysis

L4E3. Grouped data

L4E3A. Parameter estimation

L4E3A14. Normal

L4E3B. Distribution-free (nonparametric) analysis

L4E4. Two or more multivariate samples

L4E4A. Parameter estimation

L4E4A14. Normal

L5. Function evaluation (search also class C)

L5A. Univariate

L5A1. Cumulative distribution functions, probability density functions

L5A1B. Beta, binomial

L5A1C. Cauchy, chi-squared

L5A1D. Double exponential

L5A1E. Error function, exponential, extreme value

L5A1F. F distribution

L5A1G. Gamma, general, geometric

L5A1H. Halfnormal, hypergeometric

L5A1K. Kolmogorov-Smirnov

L5A1L. Lambda, logistic, lognormal

L5A1N. Negative binomial, normal

L5A1P. Pareto, Poisson

L5A1T. t distribution

L5A1U. Uniform

L5A1W. Weibull

L5A2. Inverse cumulative distribution functions, sparsity functions

L5A2B. Beta, binomial

L5A2C. Cauchy, chi-squared

L5A2D. Double exponential

L5A2E. Exponential, extreme value

L5A2F. F distribution

L5A2G. Gamma, general, geometric

L5A2H. Halfnormal

L5A2L. Lambda, logistic, lognormal  
L5A2N. Negative binomial, normal, normal scores  
L5A2P. Pareto, Poisson  
L5A2T. t distribution  
L5A2U. Uniform  
L5A2W. Weibull  
L5B. Multivariate  
L5B1. Cumulative distribution functions, probability density  
functions  
L5B1N. Normal  
L6. Pseudo-random number generation  
L6A. Univariate  
L6A2. Beta, binomial, Boolean  
L6A3. Cauchy, chi-squared  
L6A4. Double exponential  
L6A5. Exponential, extreme value  
L6A6. F distribution  
L6A7. Gamma, general (continuous, discrete) distributions, geometric  
L6A8. Halfnormal, hypergeometric  
L6A9. Integers  
L6A12. Lambda, logical, logistic, lognormal  
L6A14. Negative binomial, normal  
L6A15. Order statistics  
L6A16. Pareto, permutations, Poisson  
L6A19. Samples, stable distribution  
L6A20. t distribution, time series, triangular  
L6A21. Uniform  
L6A22. Von Mises  
L6A23. Weibull  
L6B. Multivariate

L6B3. Contingency table, correlation matrix

L6B13. Multinomial

L6B14. Normal

L6B15. Orthogonal matrix

L6B21. Uniform

L6C. Service routines (e.g., seed)

L7. Experimental design, including analysis of variance

L7A. Univariate

L7A1. One-way analysis of variance

L7A1A. Parametric analysis

L7A1A1. Contrasts, multiple comparisons

L7A1A2. Analysis of variance components

L7A1B. Distribution-free (nonparametric) analysis

L7A2. Balanced multiway design

L7A2A. Complete

L7A2A1. Parametric analysis

L7A2A1A. Two-way

L7A2A1B. Factorial

L7A2A1C. Nested

L7A2A2. Distribution-free (nonparametric) analysis

L7A2B. Incomplete

L7A2B1. Parametric analysis

L7A2B1A. Latin square

L7A2B1B. Lattice designs

L7A2B2. Distribution-free (nonparametric) analysis

L7A3. Analysis of covariance

L7A4. General linear model (unbalanced design)

L7A4A. Parametric analysis

L7A4B. Distribution-free (nonparametric) analysis

L7B. Multivariate

L8. Regression (search also classes G, K)

L8A. Linear least squares (L-2) (search also classes D5, D6, D9)

L8A1. Simple

L8A1A. Ordinary

L8A1A1. Unweighted

L8A1A1A. No missing values

L8A1A1B. Missing values

L8A1A2. Weighted

L8A1B. Through the origin

L8A1C. Errors in variables

L8A1D. Calibration (inverse regression)

L8A2. Polynomial

L8A2A. Not using orthogonal polynomials

L8A2A1. Unweighted

L8A2A2. Weighted

L8A2B. Using orthogonal polynomials

L8A2B1. Unweighted

L8A2B2. Weighted

L8A3. Piecewise polynomial (i.e. multiphase or spline)

L8A4. Multiple

L8A4A. Ordinary

L8A4A1. Unweighted

L8A4A1A. No missing values

L8A4A1B. Missing values

L8A4A1C. From correlation data

L8A4A1D. Using principal components

L8A4A1E. Using preference pairs

L8A4A2. Weighted

L8A4B. Errors in variables

L8A4D. Logistic

L8A5. Variable selection  
L8A6. Regression design  
L8A7. Several multiple regressions  
L8A8. Multivariate  
L8A9. Diagnostics  
L8A10. Hypothesis testing, inference  
L8A10A. Lack-of-fit tests  
L8A10B. Analysis of residuals  
L8A10C. Inference  
L8B. Biased (ridge)  
L8C. Linear least absolute value (L-1)  
L8D. Linear minimax (L-infinity)  
L8E. Robust  
L8F. EDA  
L8G. Nonlinear  
L8G1. Unweighted  
L8G1A. Derivatives not supplied  
L8G1B. Derivatives supplied  
L8G2. Weighted  
L8G2A. Derivatives not supplied  
L8G2B. Derivatives supplied  
L8H. Service routines  
L9. Categorical data analysis  
L9A. 2-by-2 tables  
L9B. Two-way tables  
L9C. Log-linear model  
L9D. EDA (e.g., median polish)  
L10. Time series analysis (search also class L3c5 for time series  
graphics)  
L10A. Transformations, transforms (search also class J1)

L10B. Smoothing, filtering  
L10C. Autocorrelation analysis  
L10D. Complex demodulation  
L10E. ARMA and ARIMA modeling and forecasting  
    L10E1. Model and parameter estimation  
    L10E2. Forecasting  
    L10F. Spectral analysis  
    L10G. Cross-correlation analysis  
        L10G1. Parameter estimation  
        L10G2. Forecasting  
L11. Correlation analysis  
L12. Discriminant analysis  
L13. Factor analysis  
L13A. Principal components analysis  
L14. Cluster analysis  
    L14A. Unconstrained  
        L14A1. Nested  
            L14A1A. Joining (e.g., single link)  
            L14A1B. Divisive  
        L14A2. Non-nested  
    L14B. Constrained  
        L14B1. One-dimensional  
        L14B2. Two-dimensional  
    L14C. Display  
L15. Life testing, survival analysis

## **M. Simulations, Stochastic Modeling**

M. Simulation, stochastic modeling (search also classes L6, L10)  
M1.      Simulation  
M1A.     Discrete  
M1B.     Continuous (Markov models)  
M2.     Queueing  
M3.     Reliability  
M3A.    Quality control  
M3B.    Electrical network  
M4.    Project optimization (e.g., PERT)

## N. Data Handling

```
N.    Data handling (search also class L2)
N1.    Input, output
N2.    Bit manipulation
N3.    Character manipulation
N4.    Storage management (e.g., stacks, heaps, trees)
N5.    Searching
N5A.    Extreme value
N5B.    Insertion position
N5C.    On a key
N6.    Sorting
N6A.    Internal
N6A1.    Passive (i.e. construct pointer array, rank)
N6A1A.    Integer
N6A1B.    Real
N6A1B1.    Single precision
N6A1B2.    Double precision
N6A1C.    Character
N6A2.    Active
N6A2A.    Integer
N6A2B.    Real
N6A2B1.    Single precision
N6A2B2.    Double precision
N6A2C.    Character
N6B.    External
N7.    Merging
N8.    Permuting
```

## O. Symbolic Computation

```
O.    Symbolic computation
```

## P. Computational Geometry

- P. Computational geometry (search also classes G, Q)
  - P1. One dimension
  - P2. Two dimensions
    - P2A. Points, lines
      - P2A1. Relationships
        - P2A1A. Closest and farthest points
        - P2A1B. Intersection
      - P2A2. Graph construction
        - P2A2A. Convex hull
        - P2A2B. Minimum spanning tree
        - P2A2C. Region partitioning
          - P2A2C1. Triangulation
          - P2A2C2. Voronoi diagram
      - P2B. Polygons (e.g., intersection, hidden line problems)
    - P2C. Circles
  - P3. Three dimensions
    - P3A. Points, lines, planes
    - P3B. Polytopes
    - P3C. Spheres
  - P4. More than three dimensions

## **Q. Graphics**

- Q.    Graphics (search also classes L3, P)
- Q1.    Line printer plotting

## **R. Service Routines**

- R.    Service routines
  - R1.    Machine-dependent constants  
[At LC, use these routines from MSSL3  
(via [LINMath](#), URL: <http://www.llnl.gov/LCdocs/nmg1>)  
not from SLATEC.]
  - R2.    Error checking (e.g., check monotonicity)
  - R3.    Error handling
    - R3A.    Set criteria for fatal errors
    - R3B.    Set unit number for error messages
    - R3C.    Other utility programs
  - R4.    Documentation retrieval

## **S. Software Development Tools**

- S.    Software development tools
  - S1.    Program transformation
  - S2.    Static analysis
  - S3.    Dynamic analysis

## **Z. Other Routines**

- Z.    Other

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# Keyword Index

Keyword	Description
<u>entire</u>	This entire document.
<u>title</u>	The name of this document.
<u>scope</u>	GAMS introduced, explained.
<u>availability</u>	Where related programs run.
<u>who</u>	Who to contact for assistance.
<u>gams-subject-headings</u>	Hierarchy of GAMS categories.
<u>gams-a</u>	Arithmetic, error analysis
<u>gams-b</u>	Number theory
<u>gams-c</u>	Elementary and special functions
<u>gams-d</u>	Linear algebra
<u>gams-e</u>	Interpolation
<u>gams-f</u>	Solution of nonlinear equations
<u>gams-g</u>	Optimization
<u>gams-h</u>	Differentiation, integration
<u>gams-i</u>	Differential and integral equations
<u>gams-j</u>	Integral transforms
<u>gams-k</u>	Approximation
<u>gams-l</u>	Statistics, probability
<u>gams-m</u>	Simulations, stochastic modeling
<u>gams-n</u>	Data handling
<u>gams-o</u>	Symbolic computation
<u>gams-p</u>	Computational geometry
<u>gams-q</u>	Graphics
<u>gams-r</u>	Service routines
<u>gams-s</u>	Software development tools
<u>gams-z</u>	Other routines
<u>index</u>	The structural index of keywords.
<u>date</u>	The latest changes to this document.
<u>revisions</u>	The complete revision history.

## Date and Revisions

Revision Date	Keyword Affected	Description of Change
09Dec04	<u>scope</u> <u>gams-r</u> <u>gams-c</u>	Printing instructions updated. LINMath URL added. Format problem fixed.
10Jun02	<u>gams-r</u>	MSSL3 vs SLATEC note added.
20Jul00	<u>scope</u>	LINMath replaces NMG using GAMS. New print instructions.
18Aug99	<u>scope</u>	Printing instructions added.
20Jul98	entire	First edition of LC GAMS manual.

TRG (09Dec04)

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